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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/551,233	04/17/2000	Katsuyoshi Matsuura	FUJ 99228 CIP	9686

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EXAMINER	
LEE, HSIEN MING	
ART UNIT	**PAPER NUMBER**
2823	

DATE MAILED: 11/26/2003

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	09/551,233	MATSUURA ET AL.	
	Examiner	Art Unit	
	Hsien-Ming Lee	2823	

-- The MAILING DATE of this communication appears on the cover sheet with th correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *03 September 2003*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *12,14-19 and 21-28* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *12,14-19 and 21-28* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. §§ 119 and 120

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

13)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application) since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.

a) ☐ The translation of the foreign language provisional application has been received.

14)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121 since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____ .

4) ☐ Interview Summary (PTO-413) Paper No(s). _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: .

DETAILED ACTION

Remarks

1. Claims 1-11, 13 and 20 are cancelled. Claims 12, 14-19 and 21-28 are pending in the application.

Grounds of Rejections

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 12 and 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Cuchiaro et al. (US 6,165,802) in view of Chivukula et al (US 6,146,905) and Chu et al. (US 6,287,637).

In re claims 12 and 14, Cuchiaro et al., in Figs.1-5 and related text, teach the claimed method of fabricating a semiconductor device having a ferroelectric capacitor 118, comprising the steps of:

- forming an active device element 110 on a substrate 102 (Fig.1);
- forming an insulation film 114 over said substrate 102 to cover said active device element 110 (Fig.1);
- forming a lower electrode layer 120 of said ferroelectric capacitor 118 over said insulation film 114, said lower electrode layer being formed on a layer 116 containing Ti atoms;

- forming a ferroelectric film of a PZT 122 on said lower electrode 120 as a capacitor insulation film of said ferroelectric capacitor 118 (Fig.1);
- crystallizing said ferroelectric film 122 by applying a thermal annealing process in an atmosphere containing an oxidizing gas (i.e. oxygen) (col. 8, lines 20-30); and
- forming an upper electrode layer 124 on said ferroelectric film 122 (Fig.1), wherein said step of crystallizing said ferroelectric film 122 is conducted by supplying oxygen controlled to cause an oxidation in the Ti atoms that have reached a surface of said lower electrode 120 from said layer part 116 containing Ti atoms due to the elevated temperature in the crystallizing step.

In re claim 12, Cuchiaro et al. do not teach crystallizing the ferroelectric film under a reduced total pressure in the range between 1 Torr and 40 Torr such that peeling of the ferroelectric film is substantially reduced.

However, Chu et al., in an analogous art, teach crystallizing the PZT ferroelectric film under a reduced oxygen partial pressure atmosphere (col. 6, lines 41-47) in the range of 10^{-4} to 100 Torr (col.7, line 28).

Therefore, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made, to crystallize the PZT ferroelectric film under a reduced total pressure atmosphere within the claimed range as taught by Chu et al., in the method of Cuchiaro et al., since by this manner it would produce the ferroelectric film with better performance and uniformity (col.6, lines 43-47,Chu et al.)

As far as reducing peeling of the ferroelectric film is concerned, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made, to recognize that the

semiconductor device of Cuchiaro et al. in view of Chu et al. would have the claimed feature since similar process can reasonably be expected to yield product which inherently have the same properties. *In re* Spada 15 USPQ2d 1655 (CAFC 1990); *In re* DeBlauwe 222 USPQ 191; *In re* Wiegand 86 USPQ 155 (CCPA 1950).

In re claim 14, Cuchiaro et al. do not expressly teach that the oxidizing gas contains a fraction of 1 to 20% in volume.

Chivukula et al., however, in an analogous art of forming PZT ferroelectric film, teach crystallizing the PZT ferroelectric film in an oxidizing gas containing O2/O3, wherein the O3 contains a concentration in the range of 0.5 to 12% (col. 7, lines 6-10 and 29-35).

Therefore, it would have been obvious to one of ordinary skill in the art, at the time the invention was made, to utilize the oxidizing gas of Chivukula et al in Cuchiaro's method, since by doing so it would provide a better ferroelectric performance and reduce film stress (col.7, lines 7-8 and 34-35, Chivukula et al).

In re claim 14, Cuchiaro et al. in view of Chivukula et al still do not teach the atmosphere for crystallizing said ferroelectric film containing an inert gas.

Chu et al., however, teach crystallizing the ferroelectric film in an atmosphere of containing inert gas (Ar) and an oxidizing gas (O2) (Figs. 2a-2d and col. 7, lines 14-16, 29-32).

Therefore, it would have been obvious to one of ordinary skill in the art, at the time the invention was made, to perform crystallizing in the atmosphere containing inert gas and oxidizing gas, as taught by Chu et al., in the method of Cuchiaro et al in view of Chivukula et al, since by doing so it would provide a better ferroelectric performance (col. 7, lines 37-40, Chu et al).

4. Claims 15-19 are rejected under 35 U.S.C. 103(a) as being unpatentable over Cuchiaro et al. in view of Izuha et al. (US 6,060,735) and Chu et al. (US '637).

Cuchiaro et al., in Fig.1 and related text, teach the claimed device, comprising:

- a substrate 102;
- an active device element 110 formed on a substrate 102 (Fig.1);
- an insulation film 114 provided over said substrate 102 to cover said active device element 110 (Fig.1);
- a lower electrode layer 116/120 containing Pt provided over said insulation film 114, wherein the lower electrode 116/120 comprises a *Ti layer 116* and a *conductor layer 120 (Pt)*;
- a PZT ferroelectric film 122, having *a perovskite structure*, provided on said lower electrode 120; and
- an upper electrode 124 provided on said PZT ferroelectric film 122 (Fig.1).

Cuchiaro et al. do not teach that said PZT ferroelectric film 122 has a *columnar* microstructure extending from an interface between said lower electrode 120 and said PZT ferroelectric film 122 is in a direction substantially *perpendicular to* a principal surface of said lower electrode 120, said PZT ferroelectric film 122 generally has a *<111> orientation* extending continuously from a bottom surface of said PZT ferroelectric film 122 to a top surface of said PZT ferroelectric film 122 and consisting of *crystal grains* generally having said *<111> orientation* and a substantially *uniform* grain diameter of *less than about 200 nm*.

However, Izuha et al. (Figs. 1-7), in an analogous art, teach the claimed semiconductor device, comprising a semiconductor substrate 1; a lower electrode 4 provided over the

semiconductor substrate 1; a ferroelectric PZT film 5 on said lower electrode 4 (Fig.1), said ferroelectric PZT film 5 (col. 4, lines 52-53) having a *columnar* microstructure extending from an interface between said lower electrode 4 and said ferroelectric PZT film 5 (Fig. 4A) in a direction substantially *perpendicular to* a principal surface of said lower electrode 4 (col. 2, line 57 through col.3, line 45), said ferroelectric film 5 is extending continuously from a bottom surface of said PZT ferroelectric film to a top surface of said PZT ferroelectric film and consisting of *crystal grains* having a generally *uniform* grain diameter of *less than about 200 nm* , i.e. ranging from 5 to 500 nm (col. 6, lines 52-53 and Fig.4A).

Therefore, one of ordinary skill in the art, at the time the invention was made, would have been motivated to provide the semiconductor device of Cuchiaro et al. having a columnar microstructure extending from the interface between the lower electrode and the ferroelectric film in a direction substantially perpendicular to the principal surface of said lower electrode, as taught by Izuha et al., since Cuchiaro et al., and Izuha et al. have similar structure including a laminate film of the lower electrode, the ferroelectric dielectric and the upper electrode disposed in the order; and with the structure of Cuchiaro et al., and Izuha et al. it would provide a lattice-matching structure, which, in turn, would reduce current leakage in the device (abstract, Izuha et al.).

Still, Cuchiaro et al in view of Izuha et al. do not teach that the PZT ferroelectric film generally has a <111> orientation and consists of crystal grains generally has the <111> orientation.

Chu et al., however, teach the claimed ferroelectric PZT film and crystal grains with the <111> orientation in a semiconductor device, which would improve electrical characteristics of the device (col. 3, lines 47-55).

Therefore, one of ordinary skill in the art, at the time the invention was made, would have been motivated to provide the semiconductor device of Cuchiaro et al. in view of Izuha et al. having ferroelectric PZT film with a <111> orientation and consisting crystal grains with the <111> orientation, as taught by Chu et al., since by this manner it would provide a semiconductor device having better electrical properties.

5. Claims 21-28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Cuchiaro et al. (US '802) in view of Chu et al. (US '637) and Chivukula et al. (US '905).

In re claims 21-25, 27 and 28, Cuchiaro et al., in Figs.1-5 and related text, teach the claimed method of fabricating a semiconductor device having a ferroelectric capacitor 118, comprising the steps of:

- forming an active device element 110 on a substrate 102 (Fig.1);
- forming an insulation film 114 over said substrate 102 to cover said active device element 110 (Fig.1);
- forming a lower electrode layer 120 of said ferroelectric capacitor 118 over said insulation film 114 such that the lower electrode 120 is formed on a layer 116 containing Ti (Fig.1);
- forming an amorphous ferroelectric film of a PZT (perovskite structure) 122 on said lower electrode 120 as a capacitor insulation film of said ferroelectric capacitor 118 in the form of an amorphous film (Fig.1);

- crystallizing said amorphous ferroelectric PZT film 122 by applying a thermal annealing process (step 226 in Fig. 2; col. 8, lines 21-22) in an atmosphere containing an oxidizing gas (i.e. oxygen) (col. 8, lines 20-30); and
- forming an upper electrode layer 124 on said ferroelectric film 122 (Fig.1).

Cuchiaro et al. do not teach crystallizing the amorphous PZT film in an atmosphere containing a *non-oxidizing* gas and an oxidizing gas; and after the crystallizing step performing an oxidizing treatment in an oxidizing ambient.

However, Chu et al., teach steps of crystallizing the amorphous PZT in an ambient of non-oxidizing gas (Ar) and an oxidizing gas (O2) followed by oxidizing the PZT film (Figs. 2a-2d and col. 7, lines 14-16, 29-32).

Therefore, it would have been obvious to one of ordinary skill in the art, at the time the invention was made, to perform crystallizing and oxidizing steps as taught by Chu et al. in Cuchiaro's method, since by crystallizing in the ambient of Ar and O2 it would provide a better ferroelectric performance (col. 7, lines 37-40,Chu et al.); and by subsequent oxidizing it would fill the oxygen vacancies and complete the crystalline structure of the PZT film (col. 5, lines 44-46, Chu et al.).

Furthermore, Cuchiaro et al. in view of Chu et al. also teach that the oxygen partial pressure is in the range of 10^{-4} to 100 Torr (col. 7, lines 25-28; col.8, lines 55-57; Chu et al.). With a small amount of the oxygen (col. 7, lines 11-16, Chu et al.) in the Ar/O2 ambient, it also inherently teaches that the oxygen (oxidizing gas) is within a fraction of 1 to 20% in volume. In fact, Chivukula et al., teach crystallizing the PZT ferroelectric film in an oxidizing gas containing

O2/O3, wherein the O3 contains a concentration in the range of 0.5 to 12% (col. 7, lines 6-10 and 29-35).

Therefore, it would have been obvious to one of ordinary skill in the art, at the time the invention was made, to utilize the oxidizing gas of Chivukula et al in the method of Cuchiaro et al. in view of Chu et al., since by doing so it would provide a better ferroelectric performance and reduce film stress (col.7, lines 7-8 and 34-35, Chivukula et al).

In re claim 26, Cuchiaro et al. in view of Chu et al. do not teach forming the PZT ferroelectric film by a sputtering processing.

However, Chivukula et al. teach forming the PZT ferroelectric film by a sputtering processing. (col. 3, lines 43-46, Chivukula et al)

Therefore, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made, to utilize the sputtering process of Chivukula et al for forming the PZT ferroelectric film of Cuchiaro et al. in view of Chu et al., since sputtering process is a good candidate for forming a satisfactory PZT film.

As far as reducing the density of pinholes formed in the ferroelectric film in the crystallizing step is concerned, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made, to recognize that the method of Cuchiaro et al. in view of Chu et al. and Chivukula et al. would have the claimed feature since similar process can reasonably be expected to yield product which inherently have the same properties. *In re* Spada 15 USPQ2d 1655 (CAFC 1990); *In re* DeBlauwe 222 USPQ 191; *In re* Wiegand 86 USPQ 155 (CCPA 1950).

Response to Arguments

6. Applicant's arguments filed 9/3/03 have been fully considered but they are not persuasive.

In re claim 12, applicant argued that the cited references do not teach the unexpected results reflected in the substantially reduced peeling of the ferroelectric film. (second paragraph, page 8).

In response to the argument, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made to recognize that the combined teachings do achieve the aforementioned limitation because **similar process** can reasonably be expected to yield product which inherently have the **same properties**. *In re* Spada 15 USPQ2d 1655 (CAFC 1990); *In re* DeBlauwe 222 USPQ 191; *In re* Wiegand 86 USPQ 155 (CCPA 1950).

In re claim 14,applicant also argued that the cited references are silent regarding the migration of the Ti atoms to the surface of the lower electrode or oxidation of the Ti atoms once migrated. (second paragraph, page 9).

In response to the argument, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made to recognize that the combined teachings do achieve the aforementioned limitation as a result of the elevated temperature in the crystallizing step in Cuchiaro et al. as stated above.

In re claim 15, applicant further argued that Fig. 4A in Izuha et al. is a schematic diagram and not intended to represent the relationship of actual grain diameter distribution. (third paragraph, page 10).

Contrary to the argument, Izuha et al., in col. 5, lines 3-56 and col. 6, lines 52-57, lines clearly indicate that the columnar structure (i.e. uniform columnar grains a, b and c) are successively grown in the nearly **vertical direction** to the surface of the substrate, i.e. substantially perpendicular to a principal surface of said lower electrode; and the columnar grains a, b and c are uniform in diameters , i.e. in a range of 5 ~ 500 nm in size.

In re claim 21, applicant also argued that the new limitation (i.e. the density of pinholes formed in the ferroelectric film in the crystallizing step is reduced) is taught by the cited reference. (last paragraph, page 11)

In response to the argument, it would have been obvious to one of the ordinary skill in the art, at the time the invention was made to recognize that the combined teachings do achieve the aforementioned limitation as a result of the crystallizing step since similar process can reasonably be expected to yield product which inherently have the same properties. *In re* Spada 15 USPQ2d 1655 (CAFC 1990); *In re* DeBlauwe 222 USPQ 191; *In re* Wiegand 86 USPQ 155 (CCPA 1950). In particular, the thermal annealing for crystallizing step has been known as a densification process, which, in turn, would densify the ferroelectric film, i.e. reducing the density of the pinholes.

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Hsien-Ming Lee whose telephone number is 703-305-7341. The examiner can normally be reached on M-F (9:00 ~ 5:00).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Olik Chaudhuri can be reached on 703-306-2794. The fax phone number for the organization where this application or proceeding is assigned is 703-308-7382.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0956.

Hsien-Ming Lee
Examiner
Art Unit 2823

Nov. 24, 2003